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## A CONTRIBUTION TO THE OÖLITE PROBLEM

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### INTRODUCTION

At the present time there are two prevalent theories of oölite formation, namely, the inorganic, or chemical precipitation theory, and the organic theory. Prior to the year 1890 the inorganic theory was generally agreed to and it is to this day the most widely accepted of the two.

In the year mentioned, however, Wethered<sup>1</sup> pointed out a close relationship between the concretionary structure of the calcareous algae *Girvanella* and that of true oölite, and showed that certain so-called oölites of the Carboniferous and Jurassic of England really consist, in part at least, of rounded calcareous masses secreted by this organism, since they possess in addition to the concretionary structure the vermiform tubules which characterize the genus. But in this and again in a succeeding paper, entitled "The Formation of Oölite," which appeared in 1895,<sup>2</sup> Wethered was unable to demonstrate the presence of the *Girvanella* tubules in typical oölite spherules showing both radial and concentric structure, although he was led to believe that these were also of algal origin.

Following closely upon Wethered as a champion of the organic theory came Rothpletz, who published a paper on the origin of oölite in 1892.<sup>3</sup> This investigator upon studying the recent oölites of Great Salt Lake found that where these were still in the water they were usually covered by a bluish-green algal mass consisting of the cells of *Gloeocapsa* and *Gloeotheca*, forms which are known to secrete carbonate of lime; and, when the oölite grains and rodlike

<sup>1</sup> *Quar. Jour. Geol. Soc. London*, XLVI, 270-83.

<sup>2</sup> *Ibid.*, LI, 196-209.

<sup>3</sup> *Botanisches Centralblatt*, No. 35, pp. 265-68 (English translation by F. W. Cragin, *American Geologist*, X, 279-82).

calcareous bodies on the shore were dissolved in acid, they all yielded dead and shriveled fission algae. Rothpletz, therefore, concluded that the oörites of Great Salt Lake are the product of lime-secreting fission algae, and that their formation is proceeding day by day.

Furthermore, a study of the recent and near-recent oörites of the Red Sea showed these also to contain minute grains of organic material suggesting fission algae. But these differ from the Great Salt Lake oörites in that their nuclei always consist of sand grains and in that their concentric structure is less well developed. They also possess small vermiform canals filled with calcite, which are interpreted as imprisoned algae of another type.

Rothpletz also remarks that certain elongated corpuscles possessing oölitic structures, which he interprets as organic, occurs in the Lias limestone of the Vilser Alps, and concludes as follows: "According to the present stage of my researches, I am inclined to believe that at least the majority of the marine calcareous oörites with regular zonal and radial structure are of plant origin; the product of microscopically small algae of very low rank, capable of secreting lime."

In spite of these discoveries by Wethered and Rothpletz, later students of the oölite problem have tended to drift back to the inorganic theory and to regard the association of oörites with algae as accidental. Thus Linck<sup>1</sup> has shown by experiment that oörites similar to natural ones may be produced artificially by the action of sodium carbonate and ammonium carbonate on the calcium sulphate of sea-water. He points out that these carbonates are formed by decomposition of animal and plant tissues in the sea, and favors the view that oörites have been formed in this way. That natural oörites can be formed chemically is demonstrated by Vaughan,<sup>2</sup> who points out that oölitic structure is now being developed in the calcareous muds precipitated through the agency of bacteria off the coasts of Florida and the Bahamas.

In a recent review of the whole question of oölite formation, T. C. Brown<sup>3</sup> has endeavored to substantiate Linck's conclusions

<sup>1</sup> *Neues Jahrb.*, Beil. Bd. 16 (1903), pp. 495-513.

<sup>2</sup> *Jour. Washington Acad. Sci.*, III (1913), 302-4.

<sup>3</sup> *Bull. Geol. Soc. America*, XXV (1914), 745-80.

and to discount the importance of the algal theory. To quote from him: "The dead algal cells in the Salt Lake oölite are regarded as cells which had selected the oölite as a point of attachment. They became imprisoned within it by the further accretion of aragonite by chemical precipitation." He suggests that the decay of the attached algae furnishes  $\text{Na}_2\text{CO}_3$  which acts as a precipitating agent and thereby aids the growth of the oölite.

As regards the importance of algae in the production of the oölites of Great Salt Lake, future studies may be expected to throw additional light on the problem. Microscopic examination of these by several investigators has failed to reveal any indications of algal structure in the calcareous grains themselves. On the other hand, they exhibit highly developed radial and concentric structure.

#### THE PRAIRIE DU CHIEN OÖLITE

Some time ago the writer had occasion to examine microscopically a siliceous oölite which marks the base of the Ordovician in northeastern Iowa, and found to his surprise that the oölite grains of this showed undoubted algal structures. The bed in question constitutes the so-called transition member between the Prairie du Chien dolomite and the Saint Croix sandstone. With reference to this bed Leonard, in his "Geology of Clayton County," says:

The lower Magnesian is not marked off sharply from the underlying Saint Croix, but there is a transition from the one to the other through from fifteen to twenty feet of calcareous sandstone or siliceous oölite. The rock is composed of clear rounded grains of quartz cemented by lime carbonate. In some beds this cementing material is quite abundant, in others there is only enough to hold together the grains. The ledges vary in thickness from a few inches to two or three feet. This siliceous oölite is well exposed in an old quarry in the river bluff one and one half miles above North McGregor. The transition beds are also seen in the section at Point Ann, just below McGregor. Here there are alternating layers of sandstone and limestone and some oölite similar to that described above.<sup>1</sup>

A bed of similar character and thickness has been described by Calvin<sup>2</sup> as occurring at the same horizon in Allamakee County, which lies directly north of Clayton. The writer has examined

<sup>1</sup> *Iowa Geol. Survey*, XVI (1905), 239-40.

<sup>2</sup> *Ibid.*, IV (1894), 61.

the member at the Point Ann exposure only, and the samples here described and figured are entirely from that locality.

Microscopic examination of the rock shows it to consist of imperfectly preserved siliceous oölite grains in a dolomitic matrix. The history of the rock is briefly as follows: Subsequent to the formation of the oölite, dolomitization set in, transforming the calcareous matrix completely, and many of the calcareous oölite grains either wholly or in part, to dolomite. Alteration then ceased and silicification of the unchanged, or only partly changed, oölite grains ensued. The irregular areas of dolomite within the interiors and the frayed-out borders of many of the silicified oölite grains are in this way accounted for. The structure of grains which were completely dolomitized prior to silicification is almost entirely obliterated, and these are often only with difficulty distinguished from the matrix.

The oölite grains range from 0.1 mm. to 1.13 mm. in diameter, and when well preserved show, in addition to the concentric and radial structure, minute sinuous, enwrapping fibers very similar to the tubules which characterize the *Girvanella* type of calcareous algae. A comparison of the microphotographs of the oölite grains with that of *Girvanella problematica* Nicholson, described and figured by Rothpletz, in his memoir entitled "Ueber Algen und Hydrozoen im Silur von Gotland und Oesel,"<sup>1</sup> will bring out this striking similarity (Figs. 1-6).

It should be recognized that the interwoven fibers of the oölite have been partly obliterated by silicification. Doubtless these consisted of hollow tubules filled with calcite, like those shown by *Girvanella problematica* prior to silicification.

The fibers of the organism of the oölite have an average diameter of 0.015 mm. which agrees very closely with the diameter of the tubules of *Girvanella problematica*, which varies from 0.01 to 0.018 mm., according to Rothpletz.

Typically the well-preserved oölite grains consist of an inner structureless nucleus, followed by a narrow intermediate band showing radial structure, and this again by an outer band bearing

<sup>1</sup> *Kungl. Svenska Vetenskapsakademiens Handlingar*, Band 43, No. 5 (1908), Pl. I, Fig. 1.

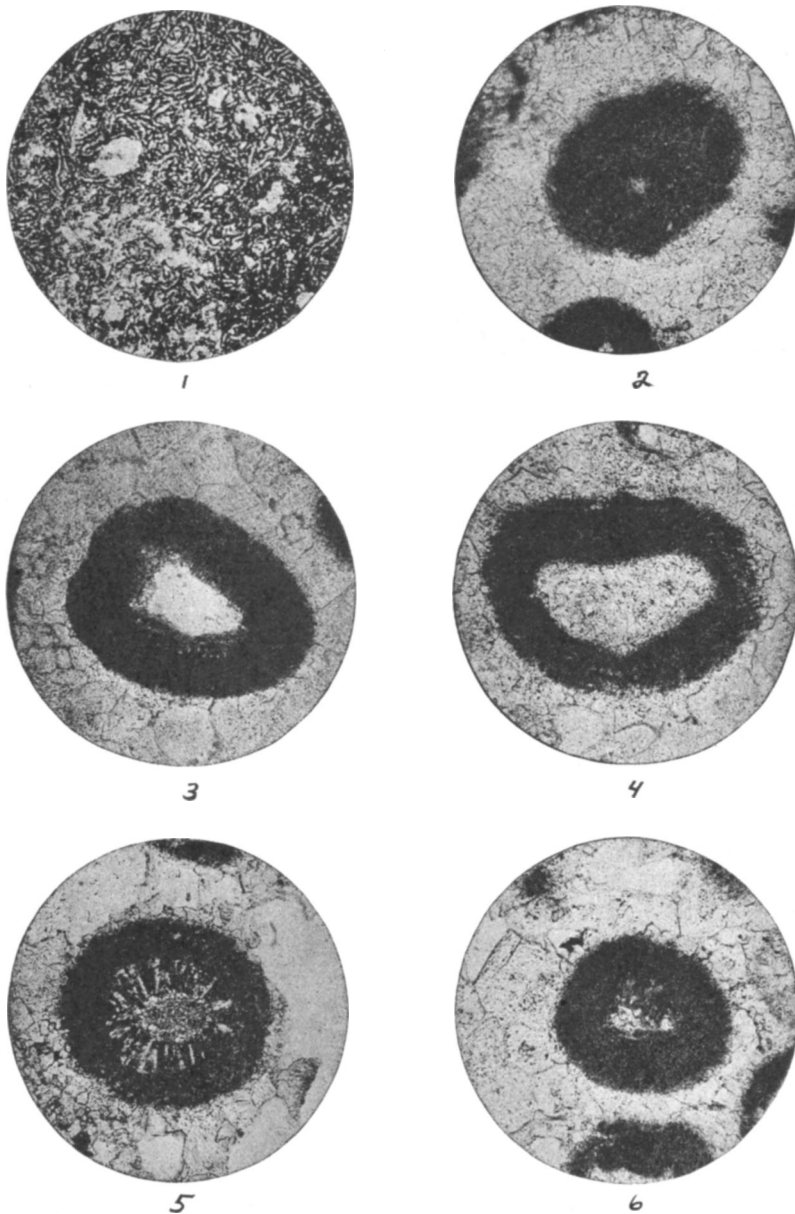


FIG. 1.—Microphotograph of *Girvanella problematica* Nicholson. About  $\times 42$ . After Rothpletz.

FIG. 2.—Microphotograph of peripheral section of a silicified oölite grain from basal Ordovician at McGregor, Iowa. About  $\times 45$ .

FIG. 3.—Cross-section of another grain from the same locality. About  $\times 45$ . Note the well-developed algal structure in the outer portion and the band showing radial structure within this. The interior is not preserved.

FIG. 4.—Imperfectly preserved oölite grain. About  $\times 45$ . The interior and peripheral portions of the grain were replaced with dolomite, with obliteration of structure, prior to silicification.

FIG. 5.—Silicified grain showing well-developed radial structure but with algal fibers nearly obliterated. About  $\times 45$ .

FIG. 6.—Another grain showing fine concentric structure but with no distinct algal fibers preserved. About  $\times 45$ .

sinuous fibers. In some instances, however, the two outer bands grade gradually into each other without any distinct line of demarkation; or indeed the radial structure may be entirely wanting and the concentric structure may continue into the nucleus. The fibers are best shown in peripheral sections of the grains. In these they appear to enwrap the bodies.

Some of the grains, however, show little or no trace of algal fibers, but there is convincing evidence that this fact has resulted in most, if not all cases, from the obliteration of original structures as an accompaniment of silicification. All stages of such obliteration may be traced under the microscope.